

## A Call to Action for Optimizing the Electronic Health Record in the Parenteral Nutrition Workflow

### Executive Summary

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## Abstract

Parenteral nutrition (PN) is a complex therapeutic modality provided to neonates, children, and adults for various indications. Surveys have shown that current electronic health records (EHRs) are in need of functionality enhancement for safe and optimal delivery of PN. This is a consensus statement from the American Society for Parenteral and Enteral Nutrition, the Academy of Nutrition and Dietetics, and the American Society of Health-System Pharmacists outlining some of the key challenges to prescribing, order review/verification, compounding, and administration of PN using EHRs today and is a call to action for clinicians and vendors to optimize their EHRs regarding the PN build and workflow.

**Key Words:** parenteral nutrition, clinical informatics, patient safety, medication errors, electronic health record

## Introduction

Parenteral nutrition (PN) is an important therapy provided to neonates, children, and adults. PN is a complex medication containing up to 40 different ingredients. <sup>1</sup> In 2013, PN was administered during approximately 302,000 hospital stays, while many other patients received this therapy in the home or long-term care settings.<sup>2</sup> The Institute for Safe Medication Practices (ISMP) classifies PN as a high-alert medication and recommends strategies be formulated to minimize harm and errors in patients receiving this medication.<sup>3</sup> PN should only be used in patients in whom the benefit outweighs the potential risks. In 2017, the American Society for Parenteral and Enteral Nutrition (ASPEN) published consensus recommendations on the appropriate use of PN.<sup>4</sup> A 2013 ASPEN survey with a gap analysis revealed only 58% of healthcare organizations have precautions in place to prevent errors and patient harm associated with PN.<sup>5</sup>

The PN process most often involves a number of basic steps, including prescribing, order review/verification, compounding, labeling, and administration. PN ordering has evolved over the years to include not only physicians as prescribers, but also dietitians, nurse practitioners, pharmacists, and physician assistants. The ASPEN Parenteral Nutrition Safety Consensus Recommendations recommended that PN shall be prescribed using standardized electronic orders via a computerized provider order entry (CPOE) system.<sup>6</sup>

In 2015, a work group was formed consisting of members from ASPEN, the Academy of Nutrition and Dietetics (Academy), and the American Society of Health-System Pharmacists (ASHP). This work group, consisting of experts in PN, electronic health record (EHR) functionality and health information technology (HIT) standards, identified areas of opportunity for optimizing the EHR in the PN process. The goals of the work group were to:

- " increase the awareness of EHR vendors to consensus recommendations and guidelines for safe PN ordering,<sup>6,7</sup>
- " recommend to EHR vendors opportunities to improve PN process functionality and clinical decision support,
- " encourage HIT standards for PN across the continuum of care, and
- " publish a joint consensus statement on PN and EHR best practices.

Key areas identified by the work group for this publication were:

1. standardized PN order and label (see Figures 1-7 in full paper for ASPEN standardized templates);
2. clinical decision support (CDS) and warnings for macronutrient and micronutrient dosing, toxicity, and incompatibilities (see Tables 1-3 in full paper for detailed limits for CDS);
3. EHR Interfaces, Interoperability, and Workflows involving ACDs - Functionality to Improve Safety and Minimize Risk of Errors (see full paper on reasons why this is important in avoiding transcription and calculation errors);
4. ordering cyclic PN, taper up, and taper down (see Table 4 in full paper for detailed recommendations on taper up and taper down schedules); and
5. transition of PN from hospital to home or other alternative care settings and vice versa (see full paper regarding the issues involving these workflows).

The work group was divided into five sub-groups with each assigned one of the above key areas of the consensus statement. Each sub-group reviewed the literature and developed evidence-based review and recommendations for their respective area. Several members of the work group combined the sections of the sub-groups and developed the rough draft of the paper. The paper was then revised based on review of the entire paper by the entire workgroup. The leaders on the work group from each organization identified appropriate members within their organization to review and submit comments on the final rough draft of the paper. The entire work group discussed and came to consensus on revisions of the paper based on reviewers' comments to form the final draft of the paper. The leaders on the work group from each organization identified and sent the final draft of the paper to the appropriate body within their organization for final review and approval on behalf of their organization.

## Summary

Ordering and managing PN therapy using EHRs is a complex and multi-step process that involves multiple clinicians from multiple different specialties. This consensus statement serves to identify the best practices to date for electronic ordering of PN using HIT. As HIT standards become more prevalent in the infrastructure of health systems, these best practices need to be integrated into evolving and mature HIT standards and the incorporation of these standards into work practices, policy, and design/build of EHR technology should result in safer processes for ordering, administering and managing PN therapy.

EHRs should include the following PN therapy functionalities:

1. Use standardized and validated PN order and labeling templates as recommended by ASPEN.
2. Design PN orders to facilitate ordering based on ASPEN recommendations and incorporate CDS to guide the prescriber on requirements and maximal limits for macronutrients and micronutrient for adult, pediatric, and neonatal patients.
3. Analyze workflow from patient-specific PN ordering to administration to the patient and documentation of delivered PN admixtures in such a way as to minimize manual human transcription or double documentation and provide appropriate CDS support in all of these steps.
4. Include the functionality to order cyclic PN with and without taper up and/or taper down.
5. Include the functionality to transition from hospital PN orders to home PN orders and vice versa.

Many of the current EHRs do not incorporate one or more of the above in their build and/or workflow. EHR vendors need to recognize these deficiencies and actively pursue the clinical nutrition expertise to enhance and optimize these areas. Nutrition support clinicians need to engage EHR vendors, the healthcare system EHR build team, and the medical and administrative leadership within their healthcare system to be involved in the process of purchasing, building, training, implementing, and optimizing their EHR to promote inclusion of the above functionalities within the PN therapy workflow. These steps will result in significant improvement in safety for patients receiving PN therapy. Optimization of the EHR and CDS does not replace the requirement that the clinicians and caregivers involved in the PN workflow must be adequately educated, trained, and experienced in PN therapy.

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Dysphagia in Nursing Homes-Results From the NutritionDay Project.

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**Abstract:** Objectives Dysphagia is a major healthcare problem as it increases the risk of malnutrition, dehydration, aspiration pneumonia, and death. The aims of this analysis of data from nursing homes (NHs) worldwide were to examine prevalence rates of dysphagia, to identify characteristics of residents with dysphagia, and to describe which type of nutrition residents with dysphagia receive. Design One-day cross-sectional study, repeated in yearly intervals since 2007. Setting 926 NH units from 19 countries. Participants NH residents participating in the nutritionDay between 2007 and 2014, aged 65 years or older, from Europe and North America, and with available information on dysphagia. Measurements Data on resident and unit level were collected on nutritionDay by local nursing staff using standardized questionnaires. Residents' nutritional status, nutritional intake, general residents' characteristics, and unit characteristics were of interest as potential predictors of dysphagia (no vs yes). Univariable generalized estimating equations were performed for all variables, and significant predictors ( $P < .01$ ) included in a multivariable analysis. Nutritional strategies (type of diet, use of oral nutritional supplements, tube feeding, and parenteral nutrition) are described for residents with and without dysphagia. Results Dysphagia was reported in 13.4% of the 23,549 residents included, with great variation in the prevalence rates between participating countries. Twelve variables of 23 remained in the multivariable model [area under the receiver operating curve = 0.898; 95% confidence interval (CI) 0.892-0.904;  $P < .001$ ]. Residents who were not able to eat

lunch orally on nutritionDay were 14.90 [odds ratio (OR); 95% CI 9.61-23.11] times more likely to have dysphagia compared with residents who ate everything. ORs of dysphagia were higher for residents with chewing problems (OR 10.48; 95% CI 8.98-12.23), immobile (OR 5.10, 95% CI 4.25-6.11) and partially mobile residents (OR 1.94; 95% CI 1.64-2.29) compared to mobile residents, and residents with severe cognitive impairment (OR 1.99; 95% CI 1.64-2.42). Poor nutritional status, digestive diseases, neurologic diseases, dehydration, and use of antibiotics were also related to a higher risk of dysphagia. The most common nutritional strategy for residents with dysphagia was providing texture-modified diet (42.5%) followed by normal diet (28.2%). One-quarter of residents with dysphagia received oral nutritional supplements additionally, 7.4% of residents with dysphagia received tube feeding exclusively, and 8.0% in combination with oral nutrition. Conclusions This analysis of NHs participating in the nutritionDay provides important insight into the current awareness of dysphagia, associated factors, and nutritional strategies. Residents who were unable to eat orally, malnourished, or dehydrated suffered more often from dysphagia, which substantiates the challenges of providing safe and adequate nutrition for residents with dysphagia. Adequacy and efficiency of different nutritional strategies need to be clarified in future studies.

Subjects: Deglutition Disorders Diet Therapy; Nursing Homes; Aged: 65+ years; Aged, 80 & over

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recommendations for their respective area. Several members of the work group combined the sections of the sub-groups and developed the rough draft of the paper. The paper was then revised based on review of the entire paper by the entire workgroup. The leaders on the work group from each organization identified appropriate members within their organization to review and submit comments on the final rough draft of the paper. The entire work group discussed and came to consensus on revisions of the paper based on reviewers' comments to form the final draft of the paper. The leaders on the work group from each organization identified and sent the final draft of the paper to the appropriate body within their organization for final review, revision, and approval on behalf of their organization.

## Opportunities for Optimizing the EHR in the PN Workflow

### 1. Standardized PN Order and Label

ASPEN recommends standardization as an error-prevention strategy for creating lasting system changes for the safe use of medications.<sup>8</sup> A 2013 PN use survey with a gap analysis reported 90 percent of organizations used a self-defined standardized PN order form.<sup>5</sup> This survey also noted only 33 percent of those surveyed (298 of 895) used a CPOE system for ordering PN. A follow-up survey was performed in 2015.<sup>9</sup> Sixty three percent (436 of 689) of the respondents replied they were using an electronic method of ordering PN. Additionally, seventy eight percent (341 of 436) of the respondents were using a self-defined standard electronic method of PN ordering with the others (95 respondents) were using a non-standard electronic method.

In 2007, ASPEN published a statement on PN standardization that advocated for a standardized process for PN management to reduce variation and promote uniformity among healthcare organizations and clinicians.<sup>8</sup> Recommended standard processes for PN in this statement included: ordering, labeling, nutritional requirements, screening, administration, and monitoring.

The 2004 ASPEN Safe Practices for Parenteral Nutrition and the 2014 ASPEN PN Safety Consensus Recommendations supported the use of standardized order formats for PN.<sup>6,10</sup> The ASPEN PN Safety Consensus Recommendations also supported standardization throughout the PN process.<sup>10</sup> The PN process included: prescribing and communicating the PN order, PN order review and verification, PN compounding, and PN administration. The Agency for Healthcare Research and Quality reported a children's hospital reduced PN errors from an average of 9 per 1000 PN orders in 2004 to approximately 2 per 1000 PN orders in 2011 by adopting a standardized PN ordering and administration process.<sup>11</sup> The ASPEN PN Safety Consensus Recommendations stated that all PN ingredients shall be ordered as amounts per day for adult patients and amounts per kilogram per day in pediatric and neonatal patients.<sup>6</sup>

PN prescribing and labeling, using an EHR, should follow templates developed by the ASPEN PN Safety Task Force as follows:<sup>1,12</sup>

- " Standardized PN ordering templates for adults and pediatric/neonatal patients (Figures 1 and 2, respectively)
- " Standardized PN labeling templates for adults and pediatric/neonatal patients (Figures 3 and 4, respectively)
- " Standardized injectable lipid emulsions (ILE) labeling templates for adults and pediatric/neonatal patients (Figures 5 and 6, respectively)
- " Standardized Home or Alternate care setting PN labeling templates (Figure 7 shows an example for adult patients)

The above templates should be adopted by clinicians and EHR vendors to bring standardization to the prescribing and labeling of PN.

## 2. CDS for Macronutrient and Micronutrient Dosing, Toxicity, and Incompatibilities

PN is a highly complex medication with multiple individual components including amino acids, dextrose, ILE, electrolytes, minerals, vitamins, trace elements, insulin, and other medications as well as solubilizers, emulsifiers, and preservatives. Given the vast complexity, PN has the potential to cause significant patient harm especially when errors occur.<sup>13,14</sup> The PN admixture needs to provide appropriate amounts of macronutrients (amino acids, carbohydrates, and lipids) and micronutrients (electrolytes, minerals, vitamins, and trace elements) for patients requiring PN based on the patient's clinical condition and laboratory status to meet the maintenance needs and prevent malnutrition in well-nourished patients and to treat deficiencies and restore health in malnourished patients (Table 1). At the same time, the PN admixture should not contain total amounts, concentrations, or rate of infusion of these nutrients that could result in toxicities or make the admixture unstable resulting in particulate matter which may include precipitates being infused into the patient, either of which could cause significant morbidity or mortality (Table 2). Recommended and maximum doses of macro- and micronutrients for neonatal and pediatric patients can be found in Table 3. Furthermore, the ASPEN clinical guidelines provide some specific metrics for use in CDS.<sup>7</sup>

There are two main types of PN admixtures, 2-in-1 (amino acids and dextrose in one bag and ILEs given as separate infusion in a different bag) and 3-in-1 (amino acids, dextrose, and ILEs infused together in same bag). When ILEs were first introduced in the United States (U.S.) in the mid-1950s, they were frequently associated with adverse reactions, varying from minor fever to potentially life threatening anaphylaxis. As a result, ILEs were removed from the market.<sup>20,34</sup> When originally developed in the late 1960's, PN only included amino acids and dextrose (2-in-1 admixture).<sup>34-36</sup>

Safer commercial ILEs using different oils were subsequently available but were infused separately from the amino acids and dextrose-based PN admixture.<sup>23,37</sup>

By 1983, the U.S. Food and Drug Administration had approved 3-in-1 PN admixtures or total nutrient admixtures (TNA) in which all 3 macronutrients, amino acids, dextrose, and ILEs, could be included in the same PN bag.<sup>20,21</sup> The TNA is an oil-in-water emulsion with tenuous thermodynamic stability. Solubilizers improve water solubility and emulsifiers can help prevent water soluble and fat soluble components in the 3-in-1 PN from becoming unstable, causing the formation of coalesced fat particles greater than 5 microns in diameter or separating out the water and fat soluble components ("cracking" the emulsion), either of which could cause severe complications or even death if infused into a patient.

Despite the non-nutrient ingredients (emulsifiers and solubilizers), the final concentrations of many of the macro- and micronutrients in the 3-in-1 PN admixture need to be kept within certain concentration thresholds to prevent the admixture from destabilizing (Table 2). The fat droplet surface in these emulsions have a net negative charge, causing an electrostatic repulsion that keeps the droplets from aggregating.<sup>37</sup> Electrolyte cations are positively charged and have the potential to destabilize the emulsion. Monovalent cations (potassium and sodium) are less likely than divalent cations to destabilize the 3-in-1 PN admixture, so they can be increased up to a total of 150 mEq/L combined concentration.<sup>20,21</sup> The divalent cations (calcium and magnesium) are much more likely to destabilize the emulsion, so they need to be limited to 20 mEq/L combined concentration.<sup>20,21</sup> Anion electrolytes (acetate, chloride, and phosphate) do not have specific concentration limits for TNAs since they are negatively charged and have little or no effect on emulsion stability.<sup>20</sup>

Calcium and phosphate are relatively insoluble and can precipitate within a PN admixture. Infusion of these precipitates can cause significant morbidity and even mortality.<sup>7,38</sup> The solubility of calcium and phosphate is not only based on the type and final concentrations of calcium and phosphate in the PN admixture but also varies based on the final concentration and distribution of amino acids, final concentration of dextrose, final concentration of magnesium, temperature at which PN is stored and administered, the final pH of the PN admixture, other components within the PN admixture, and the sequence in which the components are added to the PN admixture.<sup>7,38</sup> Keeping the final concentrations of calcium and phosphate at or below 8 mEq/L and 15 mmol/L, respectively, generally should prevent calcium phosphate precipitation (Table 2). However, this final concentration limit for phosphate is relatively conservative and could be set higher but the final concentration limits for phosphate and calcium need to be based on the calcium phosphate solubility curves specific to the PN components being used. EHRs should have the functionality of integrating the appropriate calcium phosphate solubility curves into their CDS alerts.

EHRs should provide active real time CDS alerts to prescribers at the time of order entry to ensure adequate provision of nutrients to avoid deficiencies and to prevent administering too high of a daily dose, final concentration, or rate of infusion of nutrients that could result in toxicity to the patient or instability of the PN admixture, causing complications or even death. As a safety net, the EHR should also provide CDS to pharmacists at the time of PN order verification and compounding and to nurses at the time of PN administration to avoid the above adverse outcomes. Also, the PN admixture should be included on the electronic medication administration record (MAR).

### 3. EHR Interfaces, Interoperability, and Workflows involving ACDs - Functionality to Improve Safety and Minimize Risk of Errors

ACDs should be fully integrated with EHR systems to eliminate any manual transcription, including handwritten, verbal, or fax transmission, in the PN workflow. There are a variety of different types of interfaces. The interface for PN orders should be a direct "automatic" interface that does not require any manual action by a user to transmit or download. Furthermore, PN orders should be retrieved in the ACD by scanning the PN label barcode (preferred method), by using 2 patient identifiers (e.g., patient name and date of birth), or by order ID number.

The ASPEN PN Safety Consensus Recommendations<sup>6</sup> define "fully integrated" as the PN order entered into the EHR system is transmitted electronically to the ACD without requiring re-entry of any data, and any modifications to a PN order are electronically transmitted back to the EHR system for prescriber approval and signature. This avoids errors associated with manual transcription, which has been reported as the most common cause for errors in the PN process.<sup>39-41</sup> The ASHP Guidelines for the Safe Use of Automated Compounding Devices for Preparation of PN Admixtures states that ACDs and ACD software should alert when formulation issues are identified, provide useful clinical information, integrate with existing pharmacy programs, and meet the standards of ASPEN for PN label formats.<sup>42</sup>

Sacks et al. conducted a prospective, observational study on the frequency of errors in the PN process at a large university teaching hospital.<sup>39</sup> PN errors were classified as being related to prescribing, transcription, preparation, or administration, and they categorized the severity of harm associated with the errors. Over an 18-month period, an overall error rate of 1.6% was observed, and the most common error was related to transcription (39%), which included re-entry of PN orders into the ACD. Bonnabry et al. completed a systematic risk analysis on their pediatric PN prescribing and preparation processes after implementing several changes, including the elimination of manual transcription.<sup>40</sup> The greatest risk reduction identified was in the elimination of transcription, followed by problems reading the prescription. Both errors can be eliminated by using standardized electronic orders and implementing fully integrated systems that do not require manual transcription. One retrospective cross-sectional study evaluating the impact of an interactive computerized PN worksheet (outside of the EHR system) on PN prescribing errors demonstrated a

reduction in prescribing error rate.<sup>41</sup> However, separate entry and transcription of the PN order was still required, and the errors that occurred were due to transcription or data entry mistakes.

A more recent study by MacKay, et al. in 2016 described the frequency and severity of PN errors at a large academic pediatric hospital after implementing electronic PN ordering and compounding, and this included eliminating transcription.<sup>43</sup> Over a 7-year period, the frequency of PN errors was 0.27%, compared with an error rate of 1.6% reported by Sacks et al.<sup>39</sup> In addition, 95% of errors were associated with administration, and there were no errors associated with transcription.<sup>43</sup> These data suggest that eliminating manual transcription can significantly reduce errors associated with the PN use process. This also allows the reviewing pharmacist to focus on evaluating the PN order for both clinical and formulation considerations.

One area of concern is maintaining the security of electronic systems and confidentiality of protected health information (PHI). Hilmas and Peoples described their PN process and pharmacist intervention rate.<sup>44</sup> They did not build an interface between their EHR and ACD, citing concerns about the integrity of data in their EHR by allowing access from an outside vendor. Outside vendors of ACD software should adhere to the local facility policy on patient matching and PHI security. Security of electronic systems is a primary concern, and EHR and ACD vendors should update and use the most secure methods for data transmission and storage.

There should be a standardized additive sequence in ACDs to optimize safety. The sequence of ingredients on PN admixture should match between the EHR, the ACD, and the PN label. The calculated total ingredients from ordered units of measure should be listed in matching units on the EHR, ACD, and PN label and should not require any calculation, conversion, or manipulation. These templates and calculations should be configurable for specific patient populations.

Standardized PN order formats designed with ingredients listed in the same sequence may improve consistency and potentially decrease the risk of errors, especially when transitioning care.<sup>6,10</sup> A children's hospital adopted a standardized ordering and administration process for PN and demonstrated a reduction in the average number of PN-related errors in 2004 compared to 2011 (from 9 to 2 per 1,000 PN orders).<sup>11</sup>

The ISMP has described several self-reported cases of PN-related errors, some that were near misses (i.e. potential for significant harm or death but fortunately did not occur) and others that have resulted in death. One ISMP report involved a premature infant weighing less than 1 kg who died after receiving PN with 60-times more sodium than prescribed.<sup>45</sup> There were several points of failure in this example:

" The prescriber ordered 14.7 mEq of sodium chloride and 982 mg of calcium in the PN prescription.

" The pharmacy technician had to transcribe the prescription into the ACD, and inadvertently entered the dose for calcium (982 mg) into the field for sodium chloride (in mEq). This resulted in 982 mEq of sodium chloride being compounded in the PN admixture.

" The technician affixed the label from the ACD to the PN admixture (with the incorrect sodium dose) but the pharmacist failed to identify the error

" A different label with the amounts from the original prescription (listing 14.7 mEq of sodium chloride) was placed over the label from the ACD, and the error was therefore unidentifiable by the nurse

This series of tragic errors, i.e. prescribing, transcription, labeling, and dispensing errors, highlights the need to fully integrate EHR systems with ACDs, avoid manual transcription of PN orders, optimize and utilize CDS, and match PN prescribing templates with PN templates in ACDs and on PN labels.

Another case reported to ISMP was a case of a 16-year-old boy who received a PN admixture in which the ingredients were ordered in amounts per kg, but the PN order was manually transcribed to amounts per day.<sup>46</sup> This resulted in an infusion of a hypo-osmolar PN admixture (138 mOsm/L) with very low doses of nutrients (i.e. amounts in g/day rather than g/kg/day) for almost an entire day before it was identified. Fortunately, no adverse effects were incurred by the patient. There were multiple failures across the entire medication use process in this scenario. For example, the PN order template in the EHR system did not match the template in the pharmacy system and the ACD. Furthermore, there was a lack of CDS and automated warnings in both the EHR PN order template and the ACD, a lack of redundancies in the process, and multiple points of transcription.

ISMP has provided several safe practice recommendations, in part based upon these and other reported errors:<sup>45,46</sup>

" Match prescribing and pharmacy templates

" Build, test, and heed automated warnings

" Heighten suspicions of errors

" Integrate effective redundancies

" Provide clear labeling that matches the sequence of ingredients in the PN order templates in the EHR PN order form or CPOE system and the ACD

" Educate and validate competency of all clinicians involved in the PN process

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" Eliminate manual transcription of PN orders

Total calculated ingredients in the PN bag should be displayed and available for viewing on the EHR and ACD to support prepared admixture checking between multiple systems. Calculations between the systems furthermore should allow for rounding to a specified decimal place supported by the EHR and ACD.

EHR systems, ACDs, and their interfaces should be simultaneously modifiable, with appropriate review and verification from the pharmacist, to change individual product ingredients to reflect availability, shortages, conservation, etc. and prevent the ordering of unavailable products. Medication shortages have significantly impacted patients, healthcare professionals, and health systems over the past several years. The United States Food and Drug Administration (FDA) reported 251 shortages (183 injectables) in 2011, compared to approximately 61 shortages in 2005.<sup>50</sup> They have worked with stakeholders to implement measures to avoid or prevent medication shortages, as well as improve communication from manufacturers regarding shortages. FDA's First Annual Report on Drug Shortages for Calendar Year 2013 noted that medication shortages continue to pose a challenge to public health, particularly when they involve a "critical drug," such as those used to provide PN to patients.<sup>47</sup> These efforts have contributed to a significant reduction in shortages, with the 2015 FDA report showing only 26 total, including 15 injectable medication shortages as well as prevention of a significant number of shortages (142 of which 92 were injectables).<sup>48</sup> There have been several very serious and tragic outcomes, including patient deaths, as a result of PN-related shortages, including contamination of compounded amino acid products during an amino acid shortage,<sup>49</sup> selenium deficiency in pediatric patients with intestinal failure,<sup>50</sup> and anemia and leukopenia in patients receiving long-term PN.<sup>51</sup> Mainstream media have also highlighted the devastating effects of PN-related shortages on patients, especially in children (e.g., "Children are Dying" article in *The Washingtonian* in 2013).<sup>52</sup> Of the 683 respondents to an ASPEN survey, PN-related medication shortages interfered with the ability to meet patient micronutrient (70% of respondents) or macronutrient (47% respondents) needs, and directly affected patient outcome (16% respondents).<sup>5</sup>

ISMP conducted a survey of more than 1,800 healthcare professionals (68% of which were pharmacists) in 2010.<sup>53</sup> This survey focused on medication shortages and was disseminated near the peak in medication shortages in 2011. While the survey was not specific to PN-related shortages, the results were nevertheless alarming. Approximately 35% of respondents reported a near-miss (over 1,000 near-misses reported), approximately 25% reported an error, and about 20% reported an adverse patient outcome. Many of these included medications that were high-alert or considered essential and life-saving with no suitable alternatives, including PN-related products such as intravenous (IV) electrolytes and ILEs. There was also significant frustration regarding shortages, including little or no information about the duration of a shortage (85%), the lack of advanced warning of a shortage (84%), and substantial resources spent investigating and developing a plan of action.<sup>53</sup>

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ISMP conducted another survey on PN-related shortages in 2014 and included 234 healthcare professionals (81% of which were pharmacists).<sup>54</sup> Up to 28% of respondents reported a medication error related to the inability to obtain one of the products used in PN, most commonly involving calcium gluconate, ILEs, multivitamins, sodium and potassium phosphate, and trace elements. One out of every 4 to 5 respondents reported preventable adverse outcomes due to PN-related shortages. The common contributing factors to PN shortage-related errors included:<sup>54</sup>

- " not making changes to protocols, templates, work labels, compounders, or order entry systems,
- " mix-ups between electrolyte salts,
- " confusion between pediatric and adult alternative products, and
- " differences in concentration with alternative products.

Most, if not all, of these contributing factors (and potentially the associated errors) could be avoided with enhanced functionality of CDS within and interfaces between EHRs, ACDs and pharmacy systems. Enhancements in the EHR could also improve communication to healthcare professionals regarding PN-related medication shortages. While PN-related medication shortages require a comprehensive management plan, a critical part of the plan must include enhanced functionality and optimization of EHRs, ACDs, and pharmacy systems.<sup>55,56</sup> Potential advantages and functionality can include:

- " reporting (e.g., prescribing and utilization data to guide the plan and target changes and/or education);
- " blocking products that are not available;
- " directing prescribers to appropriate alternative products;
- " using CDS (ideally at the time of order entry) to conduct automatic calculations of PN components in the background when using different products that have different components and/or different concentration of components;
- " using CDS to calculate total amounts of ordered electrolytes from multiple components within the PN; and
- " educating and communicating with healthcare professional regarding PN component and alternative product availability.

The ACD-EHR interface should transmit amounts of the calculated total ingredients, especially if electrolytes are ordered by their ions instead of by salts. ASPEN guidelines recommend salt-based ordering of electrolytes due to limitations of existing systems and EHRs to safely and appropriately



calculate the final total ingredients in the PN admixture.<sup>6</sup> Ion ordering is acceptable if the EHR can calculate and display the amounts of each electrolyte salt used to compound the PN admixture at the time of order entry, pharmacist verification, and on the label. Also, the EHR should be able to calculate and display the total amounts of electrolyte in the PN admixture, including electrolytes from the amino acid solutions as well as the ordered amounts of additional electrolytes. This is especially important when different amino acid solutions must be substituted during times of shortages.

Barcode scanning technology should be used when hanging and exchanging products used on ACDs and in compounding PN admixtures. EHR vendors should collaborate with ACD vendors and develop systems using a standardized format that will allow a direct electronic interface between any EHR and ACD systems. The Health Level Seven (HL7) version 2x clinical messaging standards are used for transmitting data from the EHR to ancillary systems. Current HL7 Version 2x standards (versioning changes with updates) have the ability to transmit patient information, insurance, diagnosis, allergies, orders for all clinical departments, results for tests ordered, and any updates of these data.<sup>57</sup> Interfaces frequently are designed to take advantage of HL7 standards to improve the speed and accuracy with which systems can be integrated.<sup>58</sup> Discussion with the HL7 Pharmacy Working Group concerning PN-specific content in evolving HL7 standards included the following suggestions:<sup>59</sup>

- " complete a use case and an activity diagram which shows possible mechanism of the PN order,
- " share ASPEN PN Safety Consensus Recommendations<sup>6</sup> with HL7 Pharmacy Work Group,
- " recommend additional work on PN orders within HL7 Standards, and
- " share ASPEN PN Safety Consensus Recommendations<sup>6</sup> with the Healthcare Information Management and Systems Society (HIMSS) EHR Association, the Office of the National Coordinator Safer Guides<sup>44</sup>, and other relevant EHR groups or alliances.

EHR-ACD interfaces should allow "versioning" to support PN order modification workflows (i.e. one order sent, then modified, most recent order should reflect changes). Currently HL7 allows for order versioning within common order segments via placer order numbers and order control field values.<sup>57</sup> A message from the ACD to the EHR to indicate whether a bag has already been prepared for that day can allow for CDS to verify order modification and reduce provider calls or waste for less significant modifications. The ACD should have alerts noting the existence of a new version of a PN order to prevent queuing an outdated admixture for compounding or to prompt the user to locate and replace an already compounded bag. ACD vendors should also develop screens similar to those currently found in clinical nutrition management software. These ACD software screens should show all PN orders and changes placed for a patient during that admission in chronological order and with placer order numbers.

Any modifications made to the PN order should be sent back to the provider for review and electronic signature. At minimum, EHR settings should be coded to require provider review when the order is placed. All PN order changes should be reviewed by a pharmacist. PN orders should be entered by a prescriber and reviewed and verified by a pharmacist within the EHR prior to order transmission to an ACD with a permanent record of the individual's name and the date and time of the order and order verification.

CDS should be used in both the EHR and the ACD.<sup>6</sup> Ideally, CDS and evaluation of the PN order should first be completed within the EHR at the time of order entry and again at the time of order review and verification. If CDS is not available within the EHR, then CDS should be available and optimized within the ACD. The EHR and ACD should allow for setting soft-stop and hard-stop CDS alerts, limit alerts, and "best practice" alerts, and these should be configurable and customizable by the healthcare system pharmacy build team.<sup>6</sup> CDS used in the EHR and ACD should be configurable to be complementary and compatible to reduce duplicative alerts and unnecessary rework. CDS used in the EHR and ACD should also be redundant when possible, in order to detect and prevent errors in interfacing and better support downtime. When it is not possible for CDS to reconcile the EHR and ACD alerts, the option for the incompatible CDS alerts to be disabled should be available.

Published data have demonstrated that using electronic systems and CDS can reduce the likelihood of errors. One systematic review suggested that most studies on HIT report positive effects on safety, quality, and efficiency.<sup>60</sup> In addition, about 78% of studies on HIT reported some positive effects on safety for a wide range of medications in a variety of healthcare settings. CDS, including automatic dose calculation features, resulted in a relative reduction in medication dosing errors by 37% to 80%.<sup>60</sup>

CDS tools should be flexible enough to accommodate practice and resource differences between institutions. This flexibility should provide the correct CDS to the right user in the ordering workflow supported at the institution. Any unique warnings or alerts that may suggest a need to modify an order should be displayed at the time of ordering and decision making to prescribers authorized to order PN therapy.

The CDS should allow customization of soft-stop and hard-stop limits for component ingredients. Furthermore, CDS should include several features, including (but not limited to):

" dosing alerts (both upper and lower limits for clinical effectiveness and stability of the PN admixture) available in all possible units of measurement (e.g., amounts per day, amounts per dose, amounts per kg per day, amounts per kg per dose, amounts per volume (L), concentration (%), etc.), taking into account whether the PN is being administered through a central or peripheral line;

- " auto-populating fields (automatically pulling in information available in the system avoiding manual entry of this information);
- " requiring mandatory fields to be completed before order entry;
- " using check-boxes or drop-down menus instead of free-text when possible; and
- " using precipitation warnings for calcium and phosphorus based on the appropriate calcium-phosphate solubility curves for PN components ordered.

Unfortunately, adoption of EHRs and CDS to improve safety of the PN process has been limited. In recent surveys, only 33% to 63% of respondents reported using an electronic order for PN and only 50% to 54% utilized dosing guidelines and CDS built into the system.<sup>5,9</sup> Furthermore, only about 28% of respondents reported that they had an automatic interface between the EHR and ACD at their institution.<sup>9</sup>

While the use of CDS can improve safety, alert fatigue (end users ignoring alerts after frequently being presented with clinically insignificant alerts) is a serious concern. Alert fatigue can be a potential barrier to successful adoption and optimization of CDS and can lead to undesirable outcomes.<sup>60</sup> In one review of 17 studies, drug safety CDS alerts were overridden in 49% to 96% of cases, and adverse events occurred in 2.3% to 6% of overridden alert cases in the three studies that reported this additional data.<sup>61</sup> Overriding an alert can be appropriate in some situations, but CDS alerts must be designed with high sensitivity and specificity to minimize alert fatigue and the need for overrides.<sup>61</sup> Many factors can contribute to alert fatigue, starting with the design of the CDS alerts, all the way through implementation and end-user interpretation. CDS must be designed to minimize "false positives", "false negatives", and unclear alerts, all of which can lead to disruptions in workflow, alert fatigue, distrust of the system, excessive overrides, unnecessary added workload, and ultimately result in adverse patient effects.<sup>61</sup> Also, for maximal efficiency, whenever possible, CDS alerts should be configured so the alert is actionable, i.e. end user can make the appropriate changes to the order with in the alert avoiding multiple clicks to make the changes.

Tools should exist in the EHR and ACD to capture failed message transfers and support downtime of the automatic interface. An error message with a description of the error (ingredient mismatch, failed transmission, etc.) should display to relevant end users to communicate failed interface messages so that the error may be addressed. The option to resubmit a message to the ACD should also exist so that the message may be retransmitted following issue resolution. In the event of a longer downtime, the ability to produce a message and manually transfer this to the ACD should also exist.

EHRs should accommodate outsourcing of PN compounding without requiring manual transcription of the PN orders. Some hospitals outsource the compounding of PN to an offsite, independent compounding pharmacy. Most of the time, the outsourced pharmacy is on a different electronic system than the hospital and may not even have access to the EHR used within the hospital, which makes it even more challenging to create a direct interface between the provider PN order entry and the ACD. This is similar to the concerns raised in issue number 5 below when transitioning PN patients from hospital to home or vice versa. These scenarios raise the issue of interoperability between different EHR systems and the importance of being able to transfer healthcare information, including complex orders such as PN, safely, efficiently, and accurately between different healthcare organizations while minimizing the need for duplicative manual entry of ordering parameters.

#### 4. Ordering Cyclic PN, Taper Up, and Taper Down

Most hospitalized patients on PN therapy receive continuous PN but some patients require cyclic PN. Cyclic PN involves infusion of the PN over certain number of hours per a 24-hour period of time and off PN the rest of that period of time. Cyclic PN may be used when a patient is being transitioned from PN to enteral or oral nutrition, preparation for transition to home PN, or if continuing cyclic PN that the patient was on prior to hospitalizations.<sup>6,62</sup> A 2010 review of the literature<sup>62</sup> on the metabolic effects of cyclic PN infusion in adults and children revealed no significant differences in nitrogen balance or circulating counter regulatory hormones comparing patients on cyclic vs. continuous PN infusion. Cyclic PN infusion may stabilize or improve elevated liver enzyme tests in patients who previously were on continuous PN infusion.<sup>62</sup> Cyclic PN infusion was not associated with any significant increase in calcium, phosphorus, magnesium, or vitamin D losses.<sup>62</sup> The ability to order cyclic PN should be included in the ordering functionality of all inpatient EHRs. Order parameters for cyclic PN should include the total volume of PN to infusion and the time period over which to infuse it, which can range from 8 hours to 20 hours with 12 hours being the most common infusion time period.

Cyclic PN can be ordered to abruptly start at the full rate at the beginning of the infusion and abruptly stop at the end of the infusion. Alternatively, the rate can be ordered to gradually taper up at the beginning of the infusion (taper up) and/or gradually taper down at the end of the infusion (taper down). Some PN infusion pumps, mostly ambulatory PN pumps, can automatically taper up and/or taper down the PN rate of infusion over the specified time period, usually one to two hours each, as well as calculate the rate to infuse the PN between the taper up and taper down periods in order to infuse the entire amount of PN ordered. If the PN infusion pump does not have this functionality, then the ordering provider will need to specify the taper up and taper down parameters as well as the rate throughout the middle of the infusion and the caregiver will need to manually change the infusion rate at the specified periods of time to the specified infusion rates.

One study<sup>63</sup> of 14 adult PN patients monitored blood samples every 5 minutes for 2 hours at the start of PN infusion without any taper up. The blood glucose level (BG) increased a mean of 60

mg/dL over the mean baseline of  $127 + 76$  mg/dL. Patients with diabetes had a higher mean increase in BG compared to non-diabetics ( $79 + 14$  mg/dL vs.  $52 + 23$  mg/dL) but there was no correlation between the amount of rise in BG and either the baseline BG or the amount of glucose infused. The majority of the rise in BG occurred in the first 60 minutes and there were no incidences of clinically significant hyperglycemia without the use of a taper up. However, in another study<sup>64</sup> of 38 adult hospitalized PN patients being transitioned from continuous to cyclic PN in preparation for discharge on home PN, 18% of the patient developed severe hyperglycemia, i.e. BG greater than 250 mg/dL, and in all of these patients, the severe hyperglycemia occurred when they were being switched from 16 hours a day to 12 hours a day. The authors recommended close monitoring of BG when transitioning from continuous to cyclic PN especially in patients with end stage liver failure, acute or chronic renal failure, insulin dependent diabetes mellitus, or decompensated congestive heart failure.

A total of 86 adult patients from four studies<sup>63,65-67</sup> who had their PN stopped abruptly with no taper down showed transient decreases in BG, mainly within the first hour after stopping the PN, with no patients experiencing symptomatic hypoglycemia. One randomized controlled trial crossover study<sup>65</sup> of 12 patients on cyclic PN comparing taper down and no taper down showed no significant differences between taper and no taper in the mean BG, insulin, epinephrine, norepinephrine, glucagon, growth hormone, or cortisol levels when checked before taper or abrupt discontinuation and every 15 minutes for 1.5 hours after discontinuation of PN.

Two studies<sup>68,69</sup> have studied taper down in pediatric patients. One study<sup>68</sup> included 14 pediatric PN patients ranging in age from  $2\frac{1}{2}$  years to 14 years, with a mean age of  $8.0 + 3.5$  years. After abrupt discontinuation of PN, the mean BG level decreased from 117 mg/dL to 83 mg/dL at 15 minutes after discontinuation with no further significant change at 30 minutes after discontinuation. Mean serum insulin levels were elevated prior to PN discontinuation and significantly dropped at 15 minutes post discontinuation with only a small further decrease at 30 minutes post discontinuation. Only one patient developed hypoglycemia, i.e. BG < 60 mg/dL, but this patient was on high-dose steroids and had a high glucose-to-insulin ratio prior to discontinuation of PN. No patients developed symptoms of hypoglycemia. Authors concluded that abrupt discontinuation of PN is safe in "most" children older than 2 years of age.

The second study<sup>69</sup> involved 11 younger pediatric PN patients (mean age 12.3 months, range 1.5 to 36 months). After abrupt discontinuation of PN, six (55%) of these patients developed hypoglycemia, defined as BG < 40 mg/dL, with stabilization of the BG in these patients ranging from 15 to 45 minutes. Ten of the patients were studied again with a 1-hour taper down before PN discontinuation, and two (20%) of these patients developed hypoglycemia. One of these patients also had developed hypoglycemia after abrupt discontinuation of PN while the other did not. Of the 8 hypoglycemic episodes, in only two instances was there any clinical sign of hypoglycemia, which was manifested by sleepiness, and in only one instance was the hypoglycemia treated. Hypoglycemic episodes did not correlate with patient's age or glucose infusion rate. Authors concluded that due to

a high incidence of hypoglycemia after abrupt discontinuation of PN in children less than 3 years of age, these patients' BG need to be closely monitored at the time of PN discontinuation. Also, a 1-hour taper down did not completely avoid hypoglycemia so a longer taper down period may be more beneficial.

The 2014 ASPEN Parenteral Nutrition Safety Consensus Recommendations<sup>6</sup> noted that adult patients usually tolerate abrupt discontinuation of PN without significant risk of hypoglycemia but that many patients on home PN are frequently ordered a 30- to 60-minute taper-down period because most ambulatory PN infusion pumps can perform this function automatically. However, the ASPEN recommendations note that pediatric patients less than 3 years of age are more prone to hypoglycemia after abrupt discontinuation of PN so require a taper down period prior to PN discontinuation. The recommendations also call for close glucose monitoring at the beginning, during, and end of infusion when transitioning patients from continuous to cyclic PN with decrease in glucose monitoring once glycemic control has been established.

The number of steps in the taper varies from one step to multiple steps and the time period of the taper varies from 30 minutes to 3 hours. So, all inpatient EHRs should have the functionality to order, document, and assist the caregiver in the performance of taper up and/or taper down of cyclic PN with a various number of steps in the taper and various length of time of the taper. EHRs should be able to accommodate at least the following regimens:

" Automatic infusion pump taper - these pumps will automatically taper the PN rate up or down over the time period specified as well as adjust the rate between taper periods to infuse the entire amount of PN ordered. So, the order needs to have the availability of a taper up and/or a taper down and each taper period needs to be able to be ordered in increments of 30 minutes from 30 minutes to 3 hours.

" Manual taper - need to have several different taper up and/or taper down regimens available (Table 4) as well as a custom taper for patients that require other taper up and/or taper down options. Also, the EHR should calculate the rate that the PN should run between taper periods to infuse the entire amount of PN ordered. The rates of infusions during the different steps in the taper up and taper down should be called out on the MAR and the EHR should have reminders in place for the nursing staff regarding when and how the rates need changed.

#### 5. Transition of PN from Hospital to Home/Alternative Care Setting and Vice Versa

Approximately 40,000 individuals in the U.S. are dependent on home PN to sustain and improve their quality of life.<sup>70,71</sup> Hospitalized patients on PN are sometimes discharged with continuation of PN in the home or alternate care setting ("home PN") and patients on "home PN" are frequently hospitalized requiring continuation of the PN during hospitalization. These scenarios require transferring the PN orders back and forth between the hospital pharmacy (or outsourced pharmacy used by the hospital) and the pharmacy preparing the PN for the patient in the home/alternative

care setting. This transition of PN orders has been challenging with many EHR's due to inability to electronically transfer orders between systems resulting in ordering home PN on paper outside of the EHR or entering "home PN" orders into the hospital EHR from a home PN bag label or paper faxed order from the "home PN" pharmacy. Both of these scenarios require manual transcription of the PN order and may involve transitioning between two PN order strategies with different component concentrations, dose units, etc., which increases the risk of misinterpretation of dosing, miscalculations, and transcription errors.

As HIT systems evolve, transmitting of a PN order to the receiving entity (hospital pharmacy to home/alternative care setting pharmacy or vice versa) electronically without the need for manual transcription is essential for patient safety and to decrease potential errors. Integrating PN recommendations into evolving HIT standards will be critical to supporting consistent, standardized PN orders, including providing complete PN orders as patients move across healthcare settings. In the U.S., transitions of care guidelines are driven by requirements of interoperability<sup>72</sup> via the Office of the National Coordinator for Health Information Technology (ONC) HIT Certification Program<sup>73</sup> and the Improving Medicare Post-Acute Care Transformation (IMPACT) Act of 2014<sup>74</sup>. The IMPACT Act points to the HL7 Consolidated Clinical Document Architecture (C-CDA) R2.1 HIT standard for electronic transitions of care guidance. While there are multiple standards which allow for including PN orders across care settings, it is critical for PN orders to be included in HIT standards guidance via the latest version of the ONC Interoperability Standards Certification (at publication, the 2015 Edition Health IT Certification Criteria)<sup>75</sup> and also to evolving HIT standards via the ONC Interoperability Standards Advisory (at publication, 2017 Final Interoperability Standards Advisory)<sup>76</sup>.

EHR systems must have the functionality to allow the provider to quickly and easily review the last PN orders within the EHR from the hospital, enter any modifications to the PN orders needed for home PN, and send these home PN orders to the home infusion company in a clear, concise and standardized fashion that is compatible with the recommended PN ordering and labeling standards and guidelines. Similar functionality should be available when ordering a PN admixture during hospitalization based on a previous "home PN" order.

## Summary

Ordering and managing PN therapy using EHRs is a complex and multi-step process that involves multiple clinicians from multiple different specialties. This consensus statement serves to identify the best practices to date for electronic ordering of PN using HIT. As HIT standards become more prevalent in the infrastructure of health systems, these best practices need to be integrated into evolving and mature HIT standards and the incorporation of these standards into work practices, policy, and design/build of EHR technology should result in safer processes for ordering, administering and managing PN therapy.

EHRs should include the following PN therapy functionalities:

1. Use standardized and validated PN order and labeling templates as recommended by ASPEN (see Figures 1-7)
2. Design PN orders to facilitate ordering based on ASPEN recommendations and incorporate CDS to guide the prescriber on requirements and maximal limits for macronutrients and micronutrient for adult, pediatric, and neonatal patients
3. Analyze workflow from patient specific PN ordering to administration to the patient and documentation of delivered PN admixtures in such a way as to minimize manual human transcription or double documentation and provide appropriate CDS support in all of these steps.
4. Include the functionality to order cyclic PN with and without taper up and/or taper down
5. Include the functionality to transition from hospital PN orders to home PN orders and vice versa

Many of the current EHRs do not incorporate one or more of the above in their build and/or workflow. EHR vendors need to recognize these deficiencies and actively pursue the clinical nutrition expertise to enhance and optimize these areas. Nutrition support clinicians need to engage EHR vendors, the healthcare system EHR build team, and the medical and administrative leadership within their healthcare system to be involved in the process of purchasing, building, training, implementing, and optimizing their EHR to promote inclusion of the above functionalities within the PN therapy workflow. These steps will result in significant improvement in safety for patients receiving PN therapy. Optimization of the EHR and CDS does not replace the requirement that the clinicians and caregivers involved in the PN workflow must be adequately educated, trained, and experienced in PN therapy.



Figure 1. Parenteral Nutrition Order Template: Adult Patient

Patient Information

Patient name \_\_\_\_\_ Medical record number \_\_\_\_\_ Birthdate/age \_\_\_\_\_

Patient location \_\_\_\_\_ Allergies \_\_\_\_\_

Height and dosing weight: Ht: \_\_\_\_\_ cm Dosing Wt: \_\_\_\_\_ kg

Diagnosis(es)/Indication(s) for PN \_\_\_\_\_

Vascular access device/location CVC type \_\_\_\_\_ Location \_\_\_\_\_

Administration date/time

Base Formula Amount/day

Amino acids g

Dextrose g

Lipids g

Electrolytes

Sodium phosphate mmol

Sodium chloride mEq

Sodium acetate mEq

Potassium phosphate mmol

Potassium chloride mEq

Potassium acetate mEq

Magnesium sulfate mEq

Calcium gluconate mEq

Vitamins, Trace Elements, Additives

Multi-component vitamins mL

Multi-component Trace elements mL

Other Additives (e.g., individual vitamins or trace elements, cysteine, regular insulin) as clinically appropriate and compatible

PN Instructions

Total volume \_\_\_\_\_ mL Infusion rate \_\_\_\_\_ mL/hr, start and stop times \_\_\_\_\_

Cycle information

Prescriber and contact information \_\_\_\_\_

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Figure 2. Parenteral Nutrition Order Template: Pediatric/Neonatal Patient

Patient Information

Patient name \_\_\_\_\_ Medical record number \_\_\_\_\_ Birthdate/age \_\_\_\_\_

Patient location \_\_\_\_\_ Allergies \_\_\_\_\_

Height and dosing weight: Ht: \_\_\_\_\_ cm Dosing Wt: \_\_\_\_\_ kg

Diagnosis(es)/Indication(s) for PN \_\_\_\_\_

Vascular access device/location CVC type \_\_\_\_\_ Location \_\_\_\_\_

Administration date/time

Base Formula Amount/kg/day

Amino acids g

Dextrose g

Lipids g

Electrolytes

Sodium phosphate mmol

Sodium chloride mEq

Sodium acetate mEq

Potassium phosphate mmol

Potassium chloride mEq

Potassium acetate mEq

Magnesium sulfate mEq

Calcium gluconate mEq

Vitamins, Trace Elements, Additives

Multi-component vitamins mL

Multi-component trace elements mL

Other Additives (e.g., cysteine, regular insulin) as clinically appropriate and compatible

PN Instructions

Total volume \_\_\_\_\_ mL Infusion rate \_\_\_\_\_ mL/hr, start and stop times \_\_\_\_\_

Cycle information

Prescriber and contact information \_\_\_\_\_

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Figure 3. Parenteral Nutrition Label Template: Adult Patient

Patient Name \_\_\_\_\_ Medical Record Number \_\_\_\_\_

Birthdate/age \_\_\_\_\_

Patient location \_\_\_\_\_

Height and dosing weight: Ht: \_\_\_\_cm Dosing Wt: \_\_\_\_\_kg

Diagnosis(es)/Indication(s) for PN \_\_\_\_\_

Vascular access device/location CVC type \_\_\_\_\_ Location \_\_\_\_\_

Administration date \_\_\_\_\_ Administration time \_\_\_\_\_

Macronutrients Amount/day

Amino acids\* g

Dextrose g

Lipids\* g

Electrolytes

Sodium phosphate mmol of phosphate (Sodium \_\_\_\_mEq)

Sodium chloride mEq

Sodium acetate mEq

Potassium phosphate mmol of phosphate (Potassium \_\_mEq)

Potassium chloride mEq

Potassium acetate mEq

Magnesium sulfate/chloride mEq

Calcium gluconate mEq

Vitamins, Trace Elements

Multi-component Vitamins\* mL

Multi-component Trace Elements\* mL

Other Additives (e.g., individual vitamins or trace elements, regular insulin)

PN Instructions

For Central (peripheral) Vein Administration Only

Total volume \_\_\_\_\_ mL Overfill volume \_\_\_\_\_ mL

Infusion rate \_\_\_\_\_ mL/h

Start and Stop times \_\_\_\_\_

Cycle information \_\_\_\_\_

Do not use after date/time \_\_\_\_\_

\*\*\*\*\* Discard any unused volume after 24 hours\*\*\*\*\*

Prescriber and Contact information \_\_\_\_\_

Institution/Pharmacy Name

Institution/Pharmacy Address

Pharmacy Telephone number

\* Specify product name

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Figure 4. Parenteral Nutrition Label Template: Pediatric/Neonatal Patient

Patient Name \_\_\_\_\_ Medical Record Number \_\_\_\_\_

Birthdate/age \_\_\_\_\_

Patient location \_\_\_\_\_

Height/Length and dosing weight: Ht/Length: \_\_\_\_\_ cm Dosing Wt: \_\_\_\_\_ kg

Diagnosis(es)/Indication(s) for PN \_\_\_\_\_

Vascular access device/location CVC type \_\_\_\_\_ Location \_\_\_\_\_

Administration date \_\_\_\_\_ Administration

Time \_\_\_\_\_

Macronutrients Amount/kg/day b

Amino acids a g

Dextrose g

Lipids a g

Electrolytes

Sodium phosphate mmol of phosphate (Sodium \_\_\_\_ mEq)

Sodium chloride mEq

Sodium acetate mEq

Potassium phosphate mmol of phosphate (Potassium \_\_\_\_ mEq)

Potassium chloride mEq

Potassium acetate mEq

Magnesium sulfate/chloride mEq

Calcium gluconate mEq

Vitamins, Trace Elements

Multi-component Vitamins a mL

Multi-component Trace Elements a mL

Other Additives

Cysteine mg/g amino acids

Others (e.g., regular insulin)

PN Instructions

For Central (peripheral) Vein Administration Only

Total volume \_\_\_\_\_ mL Overfill volume \_\_\_\_\_ mL

Infusion rate \_\_\_\_\_ mL/h

Start and Stop times \_\_\_\_\_

Cycle information \_\_\_\_\_

Do not use after date/time \_\_\_\_\_

\*\*\*\*\* Discard any unused volume after 24 hours\*\*\*\*\*

Prescriber and Contact information \_\_\_\_\_

Institution/Pharmacy Name

Institution/Pharmacy Address

Pharmacy Phone Number

a Specify product name

b Since the admixture usually contains multiple sources of sodium, potassium, chloride, acetate, and phosphorus, the amount of each electrolyte/kg provided by the PN admixture is determined by adding the amount of electrolyte provided by each salt.

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Figure 5. Standard Injectable Lipid Emulsion Label Template: Adult

Patient Name \_\_\_\_\_ Medical Record  
Number \_\_\_\_\_

Birthdate/age \_\_\_\_\_

Patient location \_\_\_\_\_

Height and dosing weight: Ht: \_\_\_\_ cm Dosing Wt: \_\_\_\_\_ kg

Diagnosis(es)/Indication(s) for PN \_\_\_\_\_

Vascular access device/location CVC type \_\_\_\_\_ Location \_\_\_\_\_

Administration date \_\_\_\_\_ Administration time \_\_\_\_\_

Infusion Volume Amount/day

Lipids a g

Instructions

For Central or Peripheral Vein Administration

Total volume \_\_\_\_\_ mL (may contain overfill)

Infusion rate \_\_\_\_\_ mL/h

Infuse over \_\_\_\_\_ h

Do not use after date/time \_\_\_\_\_

\*\*\*\*\* Discard any unused volume after 12 hours\*\*\*\*\*

Prescriber Name/Contact Information \_\_\_\_\_

Institution/Pharmacy Name

Institution/Pharmacy Address

Pharmacy Phone Number

a Specify product name

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Figure 6. Standard Injectable Lipid Emulsion Label Template: Neonate or Pediatric Patient

Patient Name \_\_\_\_\_ Medical Record Number \_\_\_\_\_

Birthdate/age \_\_\_\_\_

Patient location \_\_\_\_\_

Height/length and dosing weight: Ht/length: \_\_\_\_cm Dosing Wt: \_\_\_\_kg

Diagnosis(es)/Indication(s) for PN \_\_\_\_\_

Vascular access device/location CVC type \_\_\_\_\_ Location \_\_\_\_\_

Administration date \_\_\_\_\_ Administration time \_\_\_\_\_

Infusion Volume Amount/kg/day

Lipids a g

Instructions

For Central or Peripheral Vein Administration

Total volume \_\_\_\_\_ mL (may contain overfill)

syringe

bottle

Infusion rate \_\_\_\_\_ mL/h

Infuse over \_\_\_\_\_ h

Do not use after date/time \_\_\_\_\_

\*\*\*\*\* Discard any unused volume after 12 hours\*\*\*\*\*

Prescriber Name/Contact Information \_\_\_\_\_

Institution/Pharmacy Name

Institution/Pharmacy Address

Pharmacy Phone Number

a Specify product name

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Figure 7. Standard Home PN Label Template: Adult Patient (as an example)

Patient Name \_\_\_\_\_  
 Patient Home Address \_\_\_\_\_  
 Birthdate/Age \_\_\_\_\_  
 Height and dosing weight: Ht: \_\_\_\_cm Dosing Wt: \_\_\_\_kg  
 Vascular access device/location CVC type \_\_\_\_\_ Location \_\_\_\_\_

Administration Date/Time/Indication

Infuse 1 bag each day for nutrition.

Infuse at \_\_\_\_\_ ml per hour over \_\_\_\_\_ hours

Start at \_\_\_\_\_ (time)

Stop at \_\_\_\_\_ (time)

Macronutrients	Amount/day
Amino acids	g
Dextrose	g
Lipids	g
Electrolytes	
Sodium phosphate	mmol of phosphate (Sodium ____ mEq)
Sodium chloride	mEq
Sodium acetate	mEq
Potassium phosphate	mmol of phosphate (Potassium ____ mEq)
Potassium chloride	mEq
Potassium acetate	mEq

Magnesium sulfate/chloride mEq

Calcium gluconate mEq

Vitamins, trace elements

Multi-component Trace Elements<sup>a</sup> \_\_\_\_\_ mL to be added immediately prior to administration

Multi-component Vitamins<sup>a</sup> \_\_\_\_\_ mL to be added immediately prior to administration

Other Additives

Insulin \_\_\_\_\_ Units to be added immediately prior to administration

Medications: \_\_\_\_\_

Medication specific units (mcg, mg, g. Specific if requires adding immediately prior to administration)

Total Volume \_\_\_\_\_ mL Overfill volume \_\_\_\_\_ mL

Do not use after: Date \_\_\_\_\_ Time \_\_\_\_\_

Prescriber's name/phone number

Institution/Pharmacy Name

Institution/Pharmacy Address

Pharmacy Phone Number

<sup>a</sup> Specify product name

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Table 1. General recommendations for adult daily doses of macronutrients and micronutrients in a parenteral nutrition admixture. \*

1. Amino Acids -
  - " 0.8 to 2.5 g/kg/day (varies depending if patient normally nourished and using for maintenance therapy, malnourished and using for repletion therapy, or critically ill and using for metabolic support)<sup>1,15</sup>
  - " Approximately 20% of total energy (kcal/d)<sup>16</sup>
2. Dextrose - approximately 50% of total energy (kcal/d) and about 60% to 70% of non-protein energy (kcal/day) <sup>16</sup>
3. Fatty Acids -
  - " Provide at least 2% to 4% of total energy intake as linoleic acid and 0.25% to 0.5% as alpha linolenic acid in order to prevent essential fatty acid deficiency<sup>17</sup>
  - " Can provide fatty acids as 30% of total energy (kcal/day) and about 30% to 40% of non-protein energy/day as an alternative non-protein energy source to dextrose<sup>15,16</sup>
4. Total Energy Requirements - 20 to 30 kcal/kg/day (depending on if used for maintenance, repletion, or metabolic support therapy)<sup>1,16</sup>
5. Fluid Requirements - 30 to 40 ml/kg/day (varies based on patient's fluid status, fluid needs, and co-morbidities)<sup>1</sup>
6. Minerals -
  - " Calcium - 10 - 15 mEq/day<sup>1</sup>
  - " Magnesium - 8 - 20 mEq/day<sup>1</sup>
  - " Phosphorus - 20 - 40 mmol/day<sup>1</sup>
7. Electrolytes -
  - " Sodium - 1 - 2 mEq/kg/day<sup>1</sup>
  - " Potassium - 1 - 2 mEq/kg/day<sup>1</sup>
  - " Acetate - as needed to maintain normal acid-base balance<sup>1</sup>
  - " Chloride - as needed to maintain normal acid-base balance<sup>1</sup>
8. Vitamins - should include daily doses<sup>13,15</sup> and are usually provided by parenteral multi-vitamin products although some vitamins are available as individual parenteral products.  
Recommended daily parenteral doses:<sup>18</sup>
  - " Fat-Soluble Vitamins

- " Vitamin A - 990 mcg or 3300 IU
- " Vitamin D - 5 mcg or 200 IU (some patients may need higher doses)
- " Vitamin E - 10 mg or 10 IU
- " Vitamin K - 150 mcg

" ~~Water-Soluble~~ Vitamins

- " Vitamin B1 (thiamin) - 6 mg
- " Vitamin B2 (riboflavin) - 3.6 mg
- " Vitamin B3 (niacin) - 40 mg
- " Vitamin B5 (pantothenic acid) - 15 mg
- " Vitamin B6 (pyridoxine) - 6 mg
- " Vitamin B12 (cyanocobalamin) - 5 mcg
- " Vitamin C (ascorbic acid) - 200 mg
- " Folate - 600 mcg
- " Biotin - 60 mcg

9. Trace Elements (TE) - should include daily doses<sup>15,16</sup> and usually provided by parenteral multi-TE products although many TE are available as individual parenteral TE products. Recommended daily parenteral doses are currently in flux (see ASPEN position papers<sup>18,19</sup>)

\* These recommendations are not intended to supersede the judgment of the healthcare professional based on the circumstances of the individual patient.



Table 2. Adult limits for daily dose, final concentration, or infusion rates for macronutrients and micronutrients for 2-in-1 (dextrose and amino acids only) and 3-in-1 (dextrose, amino acids, and lipid emulsion altogether) parenteral nutrition admixtures to prevent toxicities or solubility incompatibilities. \*

1. Amino Acids -
  - " Final Concentration Limits -
  - " 2-in-1 PN - no specific limits
  - " 3-in-1 PN - should be greater than or equal to 4% to avoid destabilizing the admixture<sup>7,20,21</sup>
  - " Daily Dose - no specific limits
  - " Infusion Rates - no specific limits
  
2. Dextrose -
  - " Final Concentration Limits -
  - " 2-in-1 PN - no specific limits
  - " 3-in-1 PN - should be greater than or equal to 10% to avoid destabilizing the emulsion<sup>7,20,21</sup>
  - " Daily Dose - no specific limits
  - " Infusion Rates - generally less than or equal to 4 mg/kg/min for critically ill patients and less than or equal to 7 mg/kg/min in stable patients<sup>1</sup>, but infusion rates need to be based on patient's individual needs and co-morbidities
  - " Maintain blood glucose levels less than or equal to 180 mg/dL<sup>1</sup>
  
3. Fatty Acids (FA) -
  - " Final Concentration Limits -
  - " 2-in-1 PN - not applicable (infused separately from PN admixtures with available products of 10% or 20% ILEs)<sup>17</sup>
  - " 3-in-1 PN - should be greater than or equal to 2% to avoid destabilizing the emulsion<sup>7,20,21</sup>
  - " Daily Dose -
  - " should not exceed 60% of total energy or 2.5 g/kg/day<sup>17</sup>
  - " Infusion Rates - should be administered at a rate less than or equal to 0.11 g/kg/h to avoid overload of the reticuloendothelial system, which can cause pulmonary, hepatic, and platelet dysfunction<sup>10,21-23</sup>, in order to minimize the risk of infection, individual ILE containers should not hang any longer than 12 hours while ILE within 3-in-1 PN can hang up to 24 hours a day<sup>10,21</sup>

" Maintain serum triglyceride levels less than or equal to 400 mg/dL<sup>1</sup>

#### 4. Mineral

" Calcium \*\* - final concentration of calcium is limited by calcium/phosphorus stability curve but a safe limit is 8 mEq/L and to avoid instability for 3-in-1 PN admixtures the final concentration of the combination of magnesium and calcium should not exceed 20 mEq/L<sup>20,21</sup>

" Phosphorus \*\* - a safe final concentration is 15 mmol/L but higher limits could be administered based on the calcium/phosphorus solubility curves for the PN components being used<sup>20,24</sup>

" Magnesium - final concentration of the combination of magnesium and calcium should not exceed 20 mEq/L to avoid instability in 3-in-1 PN admixtures<sup>20,21</sup>

#### 5. Electrolytes \*

" Potassium -

" Final Concentration - should not exceed 100 mEq/L<sup>25,26</sup>

" Rate:

o Not on cardiac monitor - should not exceed 10 mEq/hr<sup>26</sup>

o On cardiac monitor - should not exceed 20 mEq/hr<sup>26</sup>

" Sodium - final concentrations of potassium and sodium combined should not exceed 150 mEq/L to avoid instability of 3-in-1 PN admixtures<sup>20,21</sup> and while there are no specific limits for 2-in-1 admixtures, exceeding 154 mEq/L of sodium will result in a hypertonic admixture and should be avoided

" Acetate - no specific limit

" Chloride - no specific limit

#### 6. Vitamins and Trace Elements - see Table 1

7. Osmolarity - no specific limits if administered via central venous catheter but should be less than or equal to 900 mosm/L if administered via peripheral vein<sup>7,15,26,27</sup>

\* These recommendations are not intended to supersede the judgment of the healthcare professional based on the circumstances of the individual patient.

\*\* Final concentrations of minerals and electrolytes for stability regarding calcium phosphorus precipitation and stability of 3-in-1 admixtures vary depending on the amino acid solution and other PN components used so should check all manufacturer's recommendations regarding limits on final concentrations of mineral and electrolyte concentrations in PN admixtures

Table 3. Recommended neonatal and pediatric daily and maximum doses of macronutrients and micronutrients in parenteral nutrition admixtures. \*

1. Amino Acids<sup>28,29</sup>
  - " Protein intake should be between 10% to 20% of the total energy in children
  - " Premature infant - 1 to 3 g/kg/day (maximum 3 to 4 g/kg/day)
  - " Less than 1 year of age - 1 to 2 g/kg/day (maximum 3 g/kg/day)
  - " 1 to 10 years of age - 1 to 2 g/kg/day (maximum 1.5 to 3 g/kg/day)
  - " More than 10 years of age (adolescents) - 1 g/kg/day (maximum 2.5 g/kg/day)
2. Total Energy Requirements<sup>28</sup>
  - " Premature infant - 120 to 150 kcal/kg/day
  - " Less than 6 months of age - 90 to 129 kcal/kg/day
  - " 6 to 12 months of age - 80 to 100 kcal/kg/day
  - " 1 to 7 years of age - 75 to 90 kcal/kg/day
  - " 7-12 years of age - 60 to 75 kcal/kg/day
  - " 12 to 18 years of age - 30 to 60 kcal/kg/day
3. Dextrose<sup>28,29</sup>
  - " Carbohydrate intake should be between 50% to 60% of the total energy for children

Dextrose Requirements

Age Group	Dextrose
Less than 1 year	Initial: 6 to 8 mg/kg/min Goal: 10 to 14 mg/kg/min Maximum: 14 to 18 mg/kg/min
1 to 10 years	Initial: 3 to 6 mg/kg/min Maximum: 8 to 10 mg/kg/min
More than 10 years	Initial: 2.5 to 3 mg/kg/min Maximum: 5 to 6 mg/kg/min
4. Fatty Acids<sup>28,30</sup>

" Fat intake should provide between 20% to 30% of the total energy (may be higher with peripheral PN)

" Maximum infusion rate should not exceed 0.15 g/kg/h

" Minimum dose needed to prevent the development of an essential fatty acid deficiency (EFAD) depends on the fatty acid source of the lipid being used. In the older patient providing at least 2% to 4% of the energy requirements from linoleic acid and 0.25% to 0.5% of the energy requirements from alpha linoleic is needed to prevent the development of EFAD. Preterm infants should receive a minimum of 0.25 g/kg linoleic acid whereas the term and older infants should receive at least 0.1 g/kg linoleic acid.

#### Fat Requirements<sup>31</sup>

Age Group      Lipids

Less than 1 year      Initial: 1 to 2 g/kg

Maximum: 3 g/kg

1 to 10 years      Initial: 1 to 2 g/kg

Maximum: 2 to 25 g/kg

More than 10 years      Initial: 1 g/kg

Maximum: 1 to 2 g/kg

#### 5. Fluid Requirements<sup>32</sup>

##### Daily Fluid Maintenance Requirement for Pediatrics

Body Weight      Amount of Fluid per Day

Less than or equal to 10 kg      100 ml/kg

Greater than 10 kg and less than or equal to 20 kg      1000 ml + 50 ml/kg over 10 kg

Greater than 20 kg      1500 ml + 20 ml/kg over 20 kg

#### 6. Minerals<sup>28,33</sup>

	Neonates	1 month to 1 year	1 to 3 years	4 to 10 years	Greater than 10 years
Calcium, mEq/kg/day	2 to 3	0.6 to 1	0.5	0.5	0.25 to 0.5

Magnesium, mEq/kg/day	0.25 to 0.5	0.5	0.5	0.5	0.25 to 0.5
-----------------------	-------------	-----	-----	-----	-------------

Phosphorus,

mmol/kg/day 1 to 2 1 0.8 0.6 0.25 to 0.5

7. Electrolytes<sup>28</sup>

	Neonates	1 month to 1 year	1 to 3 years	4 to 10 years	Greater than 10 years
Sodium, mEq/kg/day	2 to 5	3 to 4	3 to 4	2 to 3	1 to 2
Potassium, mEq/kg/day	2 to 3	2 to 3	2 to 3	2 to 3	1 to 3

8. Vitamins - should include daily doses and are usually provided by parenteral multi-vitamin products although some vitamins are available as individual parenteral products. Doses of individual vitamins dependent on age and weight.<sup>18,29,31,33</sup>

9. Trace Elements (TE) - should include daily doses and usually provided by parenteral multi-TE products although many TE available as individual parenteral TE products. Doses of individual vitamins dependent on age and weight.<sup>19,33</sup>

\* These recommendations are not intended to supersede the judgment of the healthcare professional based on the circumstances of the individual patient.

Table 4. Different manual taper up and taper down regimens that should be available within the EHR. \*

Taper Regimens		Taper Up		Taper Down	
	Time period	Rate Adjustment		Time period	Rate Adjustment
1 hour/1 step	"	Start Infusion			
"	1 hr after start infusion	"	1/2 full rate		
"	Full rate + difference to make up for taper	"		1 hr prior to end of infusion	
"	End of infusion	"	½ full rate		
"	Stop infusion				
1 hour/2 step	"	Start Infusion			
"	30 min after start infusion				
"	1 hr after start	"	1/3 full rate		
"	2/3 full rate				
"	Full rate + difference to make up for taper	"		1 hr prior to end of infusion	
"	30 min prior to end of infusion				
"	End of infusion	"	2/3 full rate		
"	1/3 full rate				
"	Stop infusion				
2 hour/2 step	"	Start Infusion			
"	1 hr after start infusion				
"	2 hrs after start	"	1/3 full rate		
"	2/3 full rate				
"	Full rate + difference to make up for taper	"		2 hrs prior to end of infusion	

- " 1 hr prior to end of infusion
- " End of infusion " 2/3 full rate
- " 1/3 full rate
- " Stop infusion

\* These recommendations are not intended to supersede the judgment of the healthcare professional based on the circumstances of the individual patient.

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